OBSERVATIONS ON THE STORAGE OF GRASS SILAGE (1)

by

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Grass silage has been defined as silage made from any uncured hay or forage crop. Its use has become widespread during the past few years and, as a result, some problems have arisen that require engineering research for solution.

Silo deterioration and failures brought demands from farmers for assistance, and to meet this demand an investigation was instigated at the New Jersey Agricultural Experiment Station in 1937 with the cooperation of the Bureau of Agricultural Chemistry and Engineering, United States Department of Agriculture, to measure the pressures exerted on silo walls by grass silage. The project has now been expanded to include investigations on juice control, protection of silos from the action of silage acids, and harvesting methods and machinery. This expansion has been materially assisted by a research grant made jointly by the American Steel and Wire Company with the Carnegie-Illinois Steel Company, the National Association of Silo Manufacturers and the Portland Cement Association.

The term "silo failure" as used in the preceeding paragraph has added significance. In the past when a silo failed it burst. Now that leakage is more prevalent, farmers have become juice conscious and are demanding silos that will not leak. The term "failure" then has gained broader meaning and a silo may be said to fail not only if it bursts but also if it leaks, deteriorates or disintegrates. While this definition may not be universally accepted, it does indicate a condition that must be met in silo design.

Juice Control

The juice in grass silage presents a sort of "poly-phase" problem. In high-moisture silage it may, and frequently does, leak or drain from the silo causing offensive odors, damage to any concrete or metal reinforcing over which it flows, and some loss of nutrients. Its control may be approached in several ways. One is to wilt the green crop in the field until its moisture content is lowered to between 65 and 70 per cent. Reports from farmers indicate some success with this method but considerable experience is required to determine when wilting has progressed to the proper stage. Wilting is also dependent on favorable weather, and the introduction of a fair weather factor in the production of grass silage is not desirable.

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A second method is to add to the chopped material some dehydrated preservative such as oat hulls or citrus pulp fortified with molasses to absorb the free moisture. It will be noted in Table I that two silos, L5, 1940 and B1, 1938, were filled using this type of preservative and that there was no leakage even with the high moisture green material. Corn meal and ground ear corn are now being tried as moisture absorbing preservatives. A third method reported as practiced by middle western farmers is to use a longer cut on the chopper when ensiling material of high moisture content. Along this same line, the Papec Machine Company is advising its customers to vary the length of cut with the condition of the green material, suggesting a 1/4 inch for low moisture, 1/2 inch for average, and 1 inch for high moisture. This sounds promising and should be investigated under controlled conditions.

In some instances it may be desirable to rid a silo of free juice. Therefore, considerable thought is being given to drainage systems for silos and to preventing seepage at points other than drains. In 1939 three drains were placed in the walls of two 18 foot silos, B4 and B5, Table I. One of the three drains was a 1.5 inch pipe placed opposite the doorway and flush with the inside wall and foundation. The other two were 2.5 inch pipes placed about 6 inches above the foundation and opposite each other in the wall midway between the first drain and the doorway. One silo was filled with 188 tons of phosphoric acid grass silage and the other was filled with 198 tons of molasses grass silage. The average moisture content of the ensiled material in each case was 68 per cent. The drainage loss from the acid silage was 975 gallons of juice, representing 2.24 per cent by weight of the ensiled material. The drainage from the molasses silage was 3,990 gallons, representing a loss of 9 per cent. A point of particular interest is that all of the juice lost from the silos came through the drains. For 1940, using the same two silos, one was filled with 333 tons of phosphoric acid grass silage and the other with 318 tons of molasses grass silage, moisture content in each case being approximately 77 per cent. The leakage loss from the acid silage amounted to almost 16 per cent, while the loss from the molasses silage was about 18 per cent of the total ensiled weight. The drains functioned but carried only part of the leakage. Most of the loss occurred around the doorway, not unexpected because of the pressure panel construction. Some leakage through the stave joints occurred up to a height of 18 feet in each silo. The joint leakage in 1940 was associated with the higher pressures which amounted to almost twice the values measured in 1939. A rock fill about 3 feet in diameter with drain in the bottom was used in silo B6 in 1940. Filled with 97 tons of phosphoric acid grass silage at 70 per cent moisture, the seepage amounted to approximately one per cent, all coming through the drain. Other types of floor drains and vertical wall drains are to be tried.

The hoops on silos B5 and B8 were tightened to produce a stress in the steel of approximately 18,000 pounds per square inch so that the staves might be held together with some force even after the silos were filled. Preliminary observations indicate that prestressed hoops will limit the leakage through the vertical joints of concrete stave silos but cannot be expected to entirely control the leakage problem because of the irregular joint surface found on concrete staves. Horizontal joint leakage was more noticeable when the vertical joint leakage was reduced. In prestressing hoops, considerable difficulty was encountered in holding the stress on intermediate hoops that do not cross the door opening but are held by spreaders. Faulty design, particularly

on spreaders carrying more than one hoop, has been evident. One common fault has been the reduction of effective area of the spreader strap by rivet holes. Improvements that have been noted include the use of continuous heavy angles along the door opening, instead of spreaders, to which the hoops are attached. The angles are held by heavy rods across the door opening at sufficiently wide intervals so as not to interfere with the removal of silage. Welding to strengthen riveted members is also in evidence.

Plastic calking was placed in most of the horizontal joints of three courses of staves in silo B8 to observe its effectiveness as a joint seal. From this one test the value of the calking may be questioned, as there was a small amount of joint leakage in the bottom two stave courses with little to choose between calked and uncalked joints. In any case, its value must be very pronounced to offset the cost of materials and application.

Coatings

To effectively seal the interior and protect the concrete stave silos, some 24 different coatings have been applied. The materials include asphalts, coal tars, oils, paraffin wax, rubber paints, synthetic resins, special plasters, varnish, and waterproofing. Results to date have not been too promising. It has been difficult to get a lasting bond between the coating and the concrete. Tests of coatings are also underway in tile block silos where difficulty has been experienced in maintaining the mortar joint and in steel silos. More durable mortar must be found for block silos as the types now used disintegrate rapidly and leave the reinforcing exposed to the action of silage acids. This will reduce the area of steel and weaken the silo if allowed to continue.

Considerable work has been done in the past on the strength and durability of concrete and concrete staves and protective coatings for concrete. Probably the most extensive work along this line has been a cooperative project between the United States Department of Agriculture and the Agricultural Experiment Station of the University of Minnesota under the direction of Mr. D. G. Miller. The results of some of these tests pertaining in particular to concrete stave silos were published as Paper No. 1713, Scientific Journal Series of the University of Minnesota. While many means of protecting concrete and mortar from acids have been studied, as yet no substitute for a rich well-proportioned mix has been found.

The Portland Cement Association has cooperated with different state agricultural experiment stations in making studies of various protective coatings for masonry silos. As a result of their work they recommend several coatings that may be effective for from 1 to 5 years. The American Concrete Institute through its committees is also investigating means of prolonging the useful life of silos.

Pressures

The equipment being used to measure pressures in silage was developed by the Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture, and is described in the Journal of the American Society of Agricultural Engineers for June 1939. Silage pressures have been measured

in 7 silos at the New Jersey Station and one at the Beltsville Research Center of the Department of Agriculture, aggregating 12 tests on grass silage and 7 on corn silage. Readings were taken as each 2 or 2-1/2 foot layer of silage was placed in the silos so that the number of individual panel readings taken during the filling of the various silos ranged from 75 to 150 with additional readings being taken each morning and evening during filling and each day during the settling period. The panels averaged about 4 square feet in area. Results are quite variable as may be seen from Figure 1, which summarizes the lateral pressures. Maximum values for grass silage vary from 159 pounds per square foot in a 12-foot diameter silo with 64 per cent moisture silage at a 25 foot head, to 1189 pounds per square foot in an 18-foot silo, with 77 per cent moisture silage at a 40-foot head. This is a range of from approximately one-half to two and one-half times the pressures commonly considered in silo design, which is 12 pounds per square foot per foot of depth.

Factors that affect the amount of lateral pressure on silo walls, in addition to depth, are the moisture content of the silage and its distribution, the preservative used, the diameter of the silo, the fineness of cut, speed of filling and type of material ensiled. The 12 tests on silo pressures with grass silage that have been run to date show the effect of moisture content and the type of preservative. Figures 2 and 3 show how the pressures in 12 and 14-foot diameter silos increase as the moisture content increases. There are some differences in the type of preservative used in these silos, but since the moisture content varies in each case and there are some differences in the materials ensiled with different preservatives no direct comparisons on the effect of preservatives can be made for these silos. Figure 4 demonstrates the effect of both moisture content and preservative in 18-foot-diameter silos. Curves 2 and 5 show the increase in pressures with molasses silage over the pressures with acid silage given in curves 1 and 4. Since the silos represented by curves 1 and 2, also those represented by curves 4 and 5, were filled simultaneously, the effects of diameter, material and moisture content were eliminated and all the differences can be attributed to the preservative. Similarly the increase in pressure found when comparing curve 1 with 4 and curve 2 with 3 and 5 can be attributed to moisture content. The fact that the curve 2 crosses curve 3 between the 25 and 30 foot levels can be ascribed to the difference in the material ensiled in the two silos and the fact that the silo represented by curve 2 had the bulk of the low moisture material in the bottom part and comparatively high moisture silage on top, while the silo represented by curve 3 was filled with silage of a uniform moisture content throughout.

Capacities

Silo capacity as well as pressure is influenced by moisture, silo size, and fineness of cut. It has been observed that with average moisture grass, taken as 65 to 72 per cent, the smaller or average sizes of silos will hold about the same tonnage of grass as corn. Table I. Those holding a greater total tonnage of grass are about balanced by those holding less. As the moisture content is increased, the total tonnage is increased and vice versa. Silos filled with high moisture grass have held up to 50 per cent greater tonnage than would be expected with normal corn silage. In each case, however, the variation of the dry matter capacity of the silo is slight.

Summary

Foundation drains show promise of satisfactory operation, particularly when pressures are not excessive.

Vertical joint leakage from concrete stave silos may be controlled to some extent by prestressing the hoops. Joints must be redesigned or provided with seals before general satisfaction can be expected.

Results of the New Jersey tests on coatings for concrete are not at all promising. However, other observations seem to indicate that varnishes and synthetic resin with wood oil vehicles, asphalts, coal tars, and Portland cement washes show promise of giving some satisfaction. In choosing an asphalt or coal tar preparation, care should be taken to select one that has a high melting point in order to minimize sticking of the silage. Some suggestions regarding silo coating are given in Bulletin CP 14 of the Portland Cement Association.

Silos should be adequately reinforced. Tables 8 and 9 in U.S.D.A. Farmers' Bulletin 1820, give reinforcing schedules that are adequate.

Silos with exposed reinforcing are likely to be more satisfactory for storing high moisture silage since such reinforcing can be prestressed, or drawn sufficiently tight when the silo is erected to overcome the effect of the silage pressures, thereby lessening the tendency for cracks to open in the walls. It can also be inspected at will and repairs or replacements easily made when necessary.

Under usual farm conditions the average size silos will hold about the same tonnage of grass as corn.

Table I

SILO INVESTIGATIONS - GRASS SILAGE DATA (1)

N. J. Agricultural Experiment Station and U. S. Department of Agriculture Cooperating

(2) Size feet	(3) Normal Capacity tons of corn silage	Green Material ensiled, tons	Preservative added: kind	Preservative added: lbs./ton	Total tonnage	(4) Moisture Content (in silo) %	(5) Settled Depth feet	Material Ensiled	(6) Ensiled Dry Matter Tons	Maximum Lateral Pressure lbs. per sq. ft.	(7) Remarks
10x25	36	36	none		36	72		Soybeans	10		U. S. D. A.
10x25	36	32	none		32	68		Alfalfa	10		U. S. D. A.
11.6x30.	64	60	Molasses	100	63	low		Timothy & clover	25		NJ,B9,1938. Mature crop, considerable spoilage in top 3rd. No leakage.
11.6x28.5	61	77	Molasses	77	80	71	24	Mixed grasses & Alfalfa	23	258, 25' head	NJ,B9,1939. Good silage, some mouldy spots near top. No leakage.
12x30	68	43	Molasses	300	49	low		Timothy	20		NJ,L4,1938. Spoilage spots throughout silage, No leakage.
12x30	68	61	Phos. Acid	16	62	av.		Oats and Peas	20		NJ,L4,1939. Excellent silage. No leakage.
12x28	61	48	Molasses & "Silo germ"	43	49	64	22.5	3rd alfalfa & oats	18	159 25' head	NJ,B6,1939. Top spoilage. No leakage. 24 t. high moist. oats on top of 24 t. low moist. alfalfa.
12x41	104	150	Molasses	125	159	78	33	2nd cutting alfalfa & clover	35	696, 40' head	NJ,B6,1938. Excellent silage. Severe leakage.
12x41	104	95	Phos. Acid	24 & 24 water	97	70	34	2nd cutting alfalfa	29	338, 40' head	NJ,B6,1940. No leakage, approx. 1% Seepage from floor drain.
14x33 inc. 6' pit	105	82	Phos. Acid	16	83	av.		Mixed Grasses	27		NJ,L2,1938. Good silage, except in pit which needed drainage. No leakage.

14 x 33 incl.6'pit	105	79	Molasses	104	83	av.		Mixed Grasses	27		NJ,L1,1938.Same as 12 above
14x43.5' incl.6'pit	150	106	None		106	66	38.5	Cereals & Alfalfa	36	310, 35'head	U.S.D.A.
14 x 30	92	62	None		62	54	25	Alfalfa	29		U.S.D.A.
14 x 37	122	58	None		58	43	30	Alfalfa	33		U.S.D.A.
14 x 41	140	102	None		102	64		Grasses, Vetch & Alfalfa	37		U.S.D.A.
14 x 42	144	135	Molasses	87	141	71	36	2ndAlfalfa	41	520, 40' head	NJ,B8,1940, Some leakage,approx. 2% loss, cutter set at 1/4" cu
14 x 43.5	150	106	None		106	67	38	Cereals, Vetch & Alfalfa	35		U.S.D.A.
14.3 x 35	118	110	Oat Hulls with 40% Molasses	100	115	74	28	Oats and Peas	30	581, 30' head	NJ,L5,1940. No leakage
16 x 41	183	154	Molasses	42	157	low		Alfalfa, Clover & Timothy	63		NJ,B7,1937. Top 10' spoiled. No leakage
16 x 41	183	138	Molasses	100	145	63		Mixed Grasses	54		NJ,B7,1938. Mature cr Considerable spoilage No leakage.
18 x 31.5	161	188	Molasses	106	198	68	27.5	Alfalfa & Clover	63	527, 30' head	NJ,B5,1939. Good sila 9% seepage loss thru drains.
18 x 32.5	168	186	Phos. Acid	20	188	68	27.5	Alfalfa & Clover	60	431, 32.5' head	NJ,B4,1939. Good sila 2.24% seepage loss thru drains.
18 x 35	187	180	Citrus Pulp & Mol. Dry	100	189	75 Gr. mat.		Oats and Peas			NJ,B1,1938. Top 6' spoiled, rest very good. No leakage.
18 x 40	224	261	Molasses	27	265	av.		Alfalfa, Clover & Timothy			NJ,B5,1937. Poor silage, very offensi odor. Mouldy spots. Leakage at doors.

18 x 40	224	200	Molasses	100	210	low		Mixed Grasses	84		NJ, B5, 1938. Top spoiled, also along sides down 10'. No leakage
18 x 40	224	330	Phos. Acid	20	333	77	35	Alfalfa	77	950, 40' head	NJ, B4, 1940. Severe leakage, approx. 16% loss.
18 x 41	231	308	Molasses	66	318	77	35	Alfalfa	73	1189, 40' head	NJ, B5, 1940. Severe leakage, approx. 18% loss.
18 x 42	237	332	Molasses	100	349	high		Alfalfa & Clover	80		NJ, B3, 1938. Excellent silage. Severe leakage
18 x 42.5	240	263	Molasses	40	268	72	37	Oats and Peas	75	801, 42.5' head	NJ, B2, 1937. Good silage. Leakage from low 5' about 3 weeks afte fill.

Notes

(1) Messrs. Claude Eby and W. H. Tamm, N. J. Agr. Exp. Sta., assisted in preparing data for table.
(2) Refers to silo diameter and depth of silage immediately after filling.
(3) From U. S. D. A. Farmers' Bulletin 1820.
(4) Low moisture content assumed to be below 65%, average 65-72%, high over 72%.
(5) 30 days after filling.
(6) For approximate values, low moisture taken as 60%, average as 68%, high as 77%.
(7) N. J. cutters set for 1/2" cut except as noted.
All N. J. silos sealed with mulch paper covered with at least a ton of chopped grass.
Spoilage refers to silage unsuitable for feed below seal.

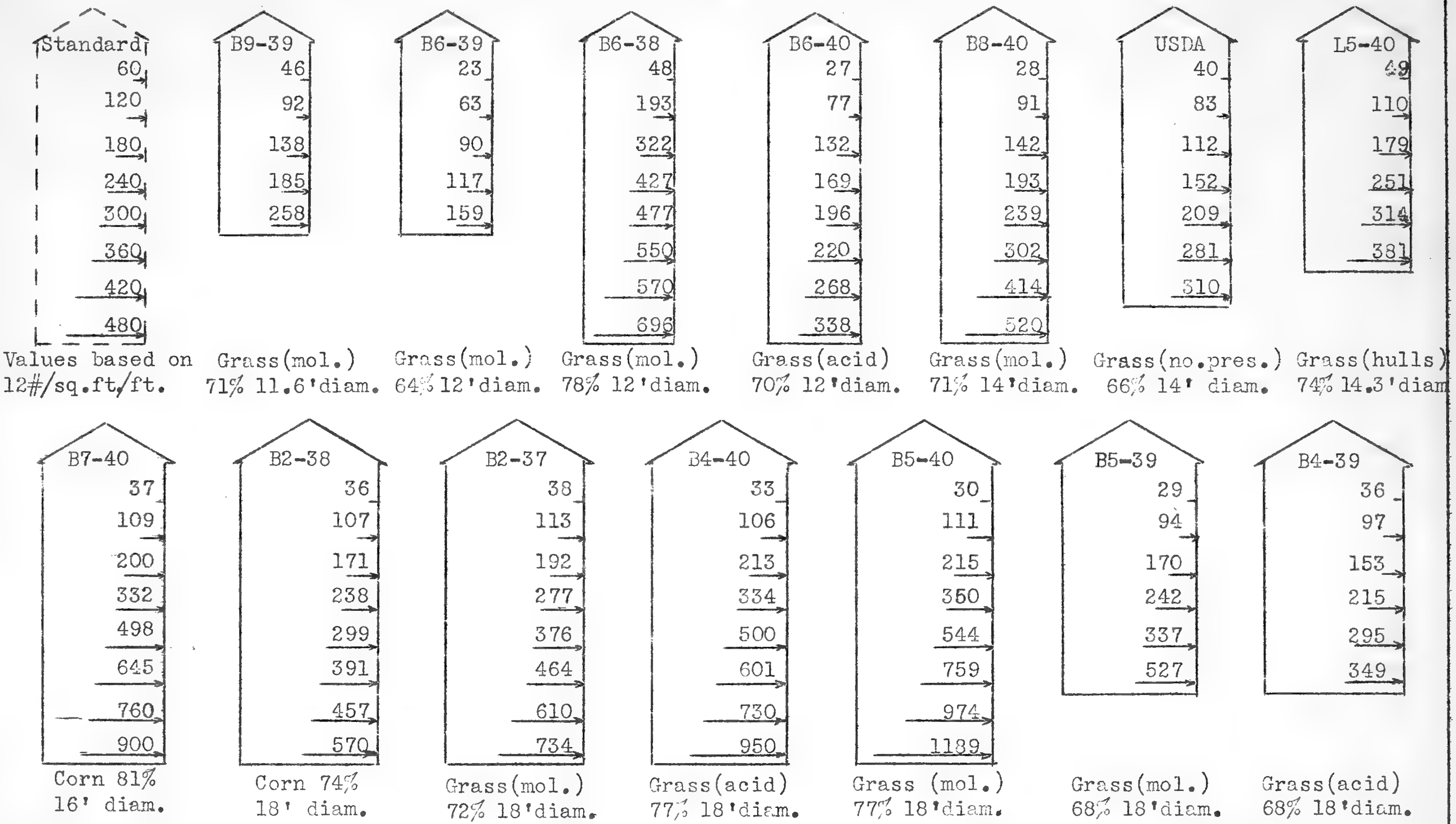
Silo Types

N. J. B1 to B8 incl. - concrete stave.
N. J. B9, L5 - steel.
N. J. L1, L2 - wood with 6' poured concrete pit.
N. J. L4 - tile stave.

Figure 1.

Silo Pressure Investigations

New Jersey Agricultural Experiment Station and U. S. Department of Agriculture Cooperating



Lateral pressures (lbs. per sq. ft.) are shown at 5 ft. intervals in both corn and grass silage. Different preservatives, moisture contents and silo diameters are given. Supporting data may be found in Table 1, key numbers appearing under "Remarks". Pressures for "Standard" based on empirical value of 12 lbs./sq.ft./ft. of depth.

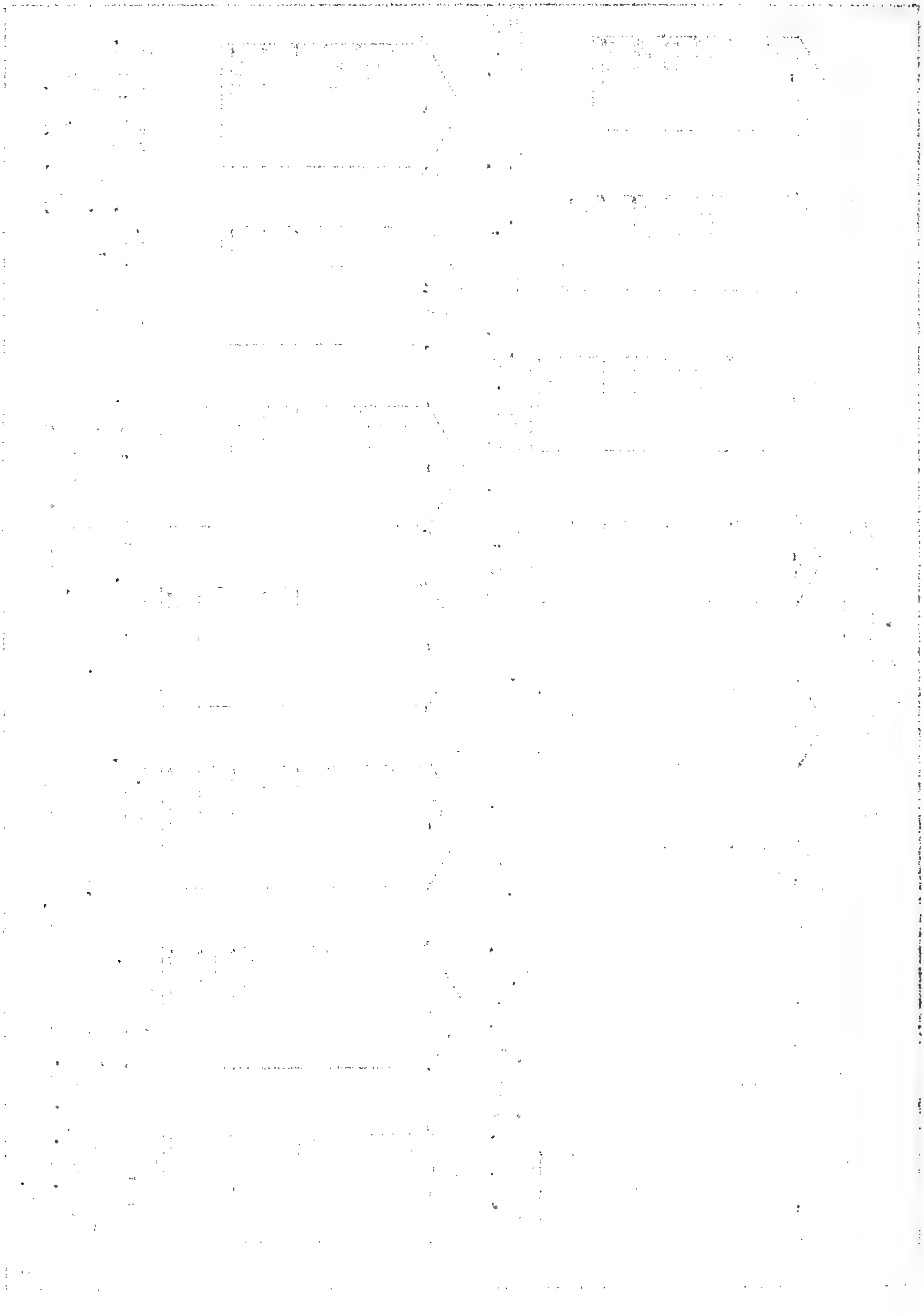
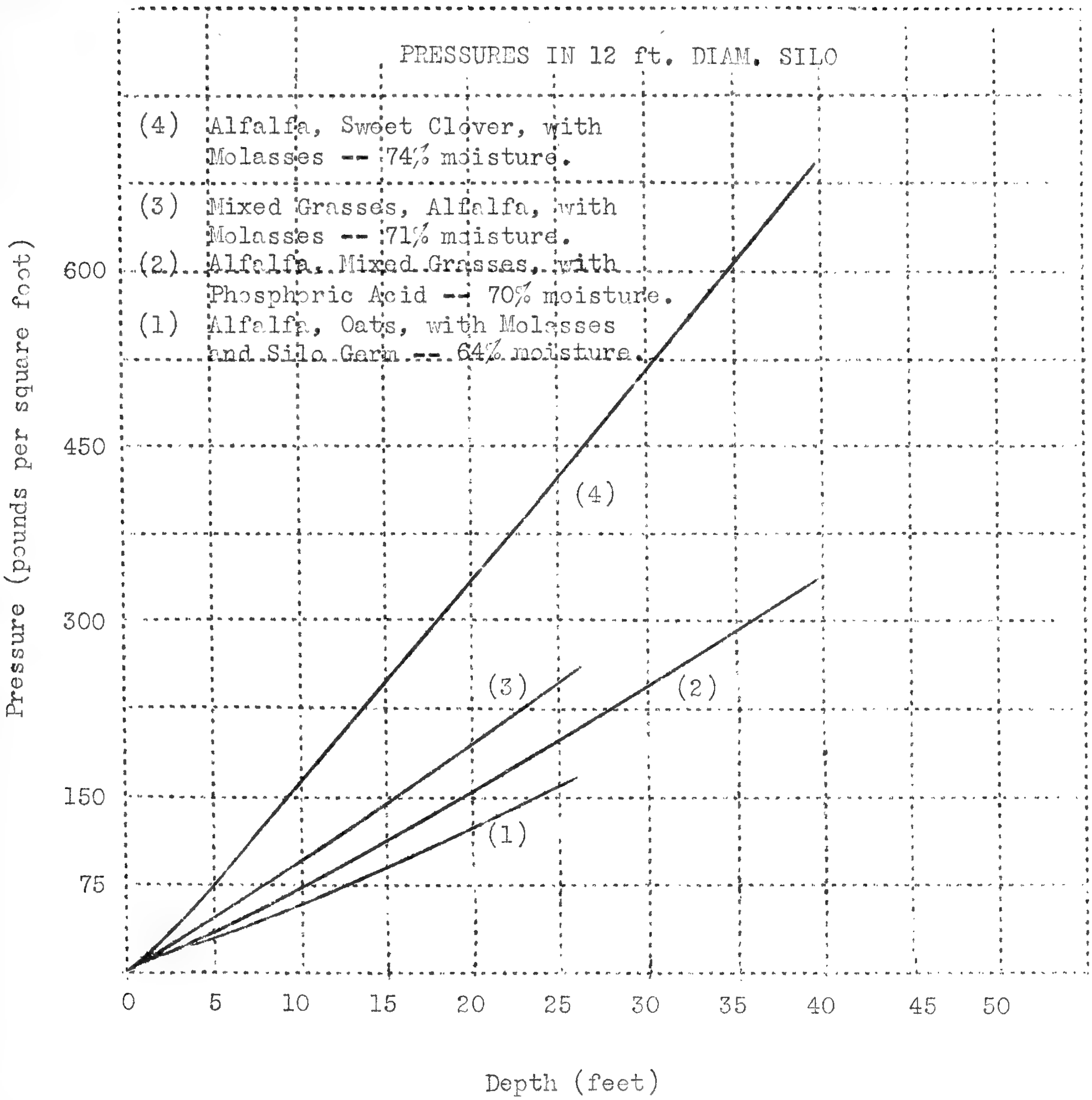


Figure 2.



PRESSURES IN 12 ft. DIAM. SILO
(4) Alfalfa, Sweet Clover, with Molasses -- 74% moisture.
(3) Mixed Grasses, Alfalfa, with Molasses -- 71% moisture.
(2) Alfalfa, Mixed Grasses, with Phosphoric Acid -- 70% moisture.
(1) Alfalfa, Oats, with Molasses and Silo Garn -- 64% moisture.
Pressure (pounds per square foot)
600
450
300
150
75
(4)
(3)
(2)
(1)
0
5
10
15
20
25
30
35
40
45
50
Depth (feet)

Figure 3.

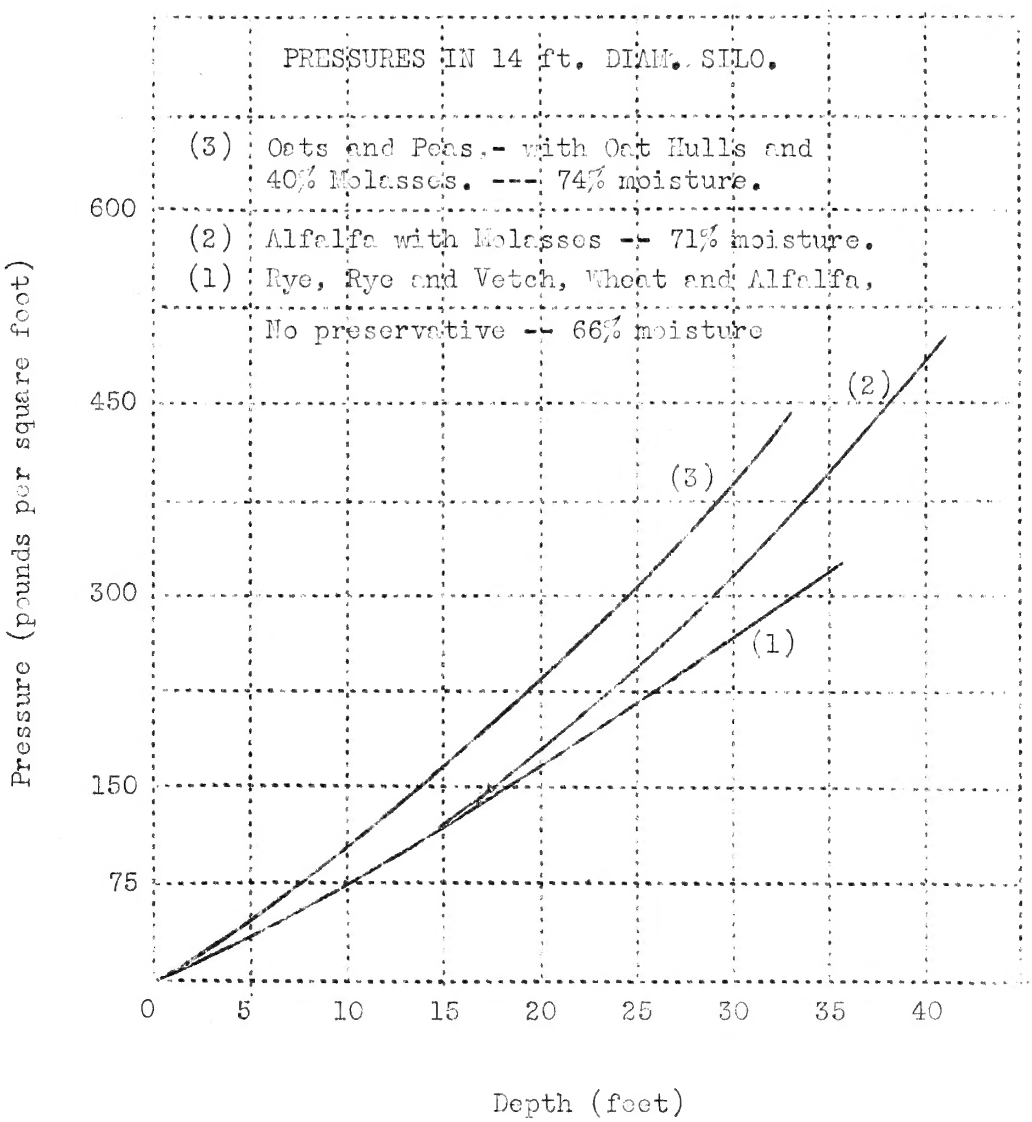
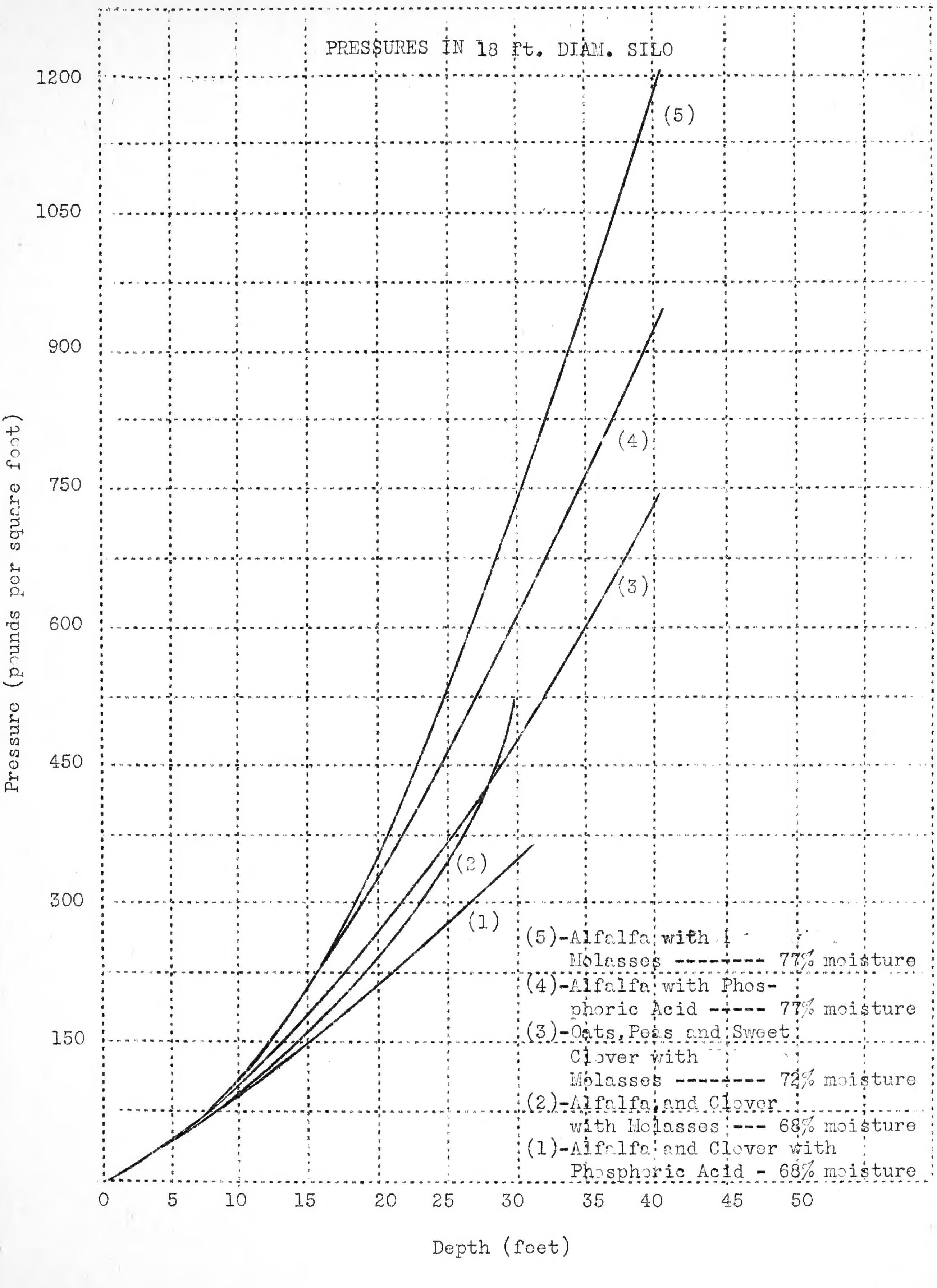

PRESSURES IN 14 ft. DIAM. SILO.
(3) Oats and Peas.- with Oat Hulls and 40% Molasses. --- 74% moisture.
(2) Alfalfa with Molasses -- 71% moisture.
(1) Rye, Rye and Vetch, Wheat and Alfalfa, No preservative -- 66% moisture
Pressure (pounds per square foot)
600
450
300
150
75
0
5
10
15
20
25
30
35
40
(1)
(2)
(3)
Depth (feet)

Figure 4.


PRESSURES IN 18 ft. DIAM. SILO
Pressure (pounds per square foot)
1200
1050
900
750
600
450
300
150
0
5
10
15
20
25
30
35
40
45
50
Depth (feet)
(5)
(4)
(3)
(2)
(1)
(5)-Alfalfa with
Molasses -------- 77% moisture
(4)-Alfalfa with Phos-
phoric Acid ----- 77% moisture
(3)-Oats, Peas and Sweet
Clover with
Molasses -------- 72% moisture
(2)-Alfalfa and Clover
with Molasses --- 68% moisture
(1)-Alfalfa and Clover with
Phosphoric Acid - 68% moisture